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THE EFFECT OF PROCEDURAL VARIATIONS IN THE USE OF TARGET IDENTIFICATION AND AIRBORNE POSITION INFORMATION EQUIPMENT ON THE PERFORMANCE OF A SIMULATED RADAR APPROACH CONTROL SYSTEM

ROBERT G. KINKADE AND J. S. KIDD

LABORATORY OF AVIATION PSYCHOLOGY
THE OHIO STATE UNIVERSITY
AND
THE OSU RESEARCH FOUNDATION

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UNITED STATES AIR FORCE
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FOREWORD

This report covers part of the research on man-machine systems being conducted by the Laboratory of Aviation Psychology and the Department of Electrical Engineering of The Ohio State University, with Dr. George E. Briggs as Principal Investigator. The objectives of this research are: (1) the development of new human factors methodology for studying man-machine systems, (2) the application of new methodology to several different types of systems in order to modify and improve the validity and generality of concepts, (3) the development of human factors principles for the analysis and synthesis of systems, and (4) the formulation of human factors principles and information in terms compatible with standard engineering practice.

The present report was prepared for the Engineering Psychology Branch, Aero Medical Laboratory, Directorate of Laboratories, Wright Air Development Center, under Contract No. AF 33(616)-3612, Project 7184, Task 71583, with Dr. James C. McGuire acting as Task Scientist. This work was initiated under Contract No. AF 33(616)-43 with Dr. Ralph W. Queal, Jr. acting as Project Scientist and Dr. Paul M. Fitts as Principal Investigator.

The authors are indebted to members of the staff of the Laboratory of Aviation Psychology for their continuing interest and help in the planning of the research and the preparation of the manuscript. They also thank Capt. H.B. Hall, Capt. V. T. Wood, Jr., Capt. Wm. J. Hamilton, and Mr. John Legg of the Operations Section, Air Traffic Analysis Branch, Test Engineering Division, Directorate of Flight and All Weather Testing, Wright Air Development Center, for their generous cooperation.

ABSTRACT

Two experimental steps were employed to evaluate the interaction effects of Airborne Position Information equipment and continuous target identification in a simulated radar approach control task. Several variations in the procedures and system configuration were also compared.

Ten laboratory-trained controllers participated. The results led to the conclusion that some of the functional characteristics of API and target ID are interchangeable in that API provides an independent method of target identification. Ground reference points and fixed approach paths employed as possible aids in the use of the API facility proved to interfere with the flexibility of operations.

PUBLICATION REVIEW

This report has been reviewed and is approved.

FOR THE COMMANDER:

Walter F. Grether

WALTER F. GRETHER
Director of Operations
Aero Medical Laboratory

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THE EFFECT OF PROCEDURAL VARIATIONS IN THE USE OF TARGET IDENTIFICATION AND AIRBORNE POSITION INFORMATION EQUIPMENT ON THE PERFORMANCE OF A SIMULATED RADAR APPROACH CONTROL SYSTEM

INTRODUCTION

A series of studies separately evaluating the use of target identification displays and displays of airborne position information (4, 8, 9) has led to the conclusion that such displays will materially benefit the performance of a radar approach control system. The present study is an effort to examine the combined effect of these two types of displays with special attention directed toward various techniques for controller utilization of airborne position information (API) equipment potentialities.

From previous results, several possibilities from the combination of target identification and API could be inferred. First, the use of the two types of displays in combination might be mutually facilitative—leading perhaps to heightened performance. A second possibility is that the combination might not yield anything superior to one or another display used alone. Both of these alternatives represent possible interactions between the use of target identification and API.

A secondary aspect of the study was concerned with variations in the way in which the API equipment could be employed. In a previous experiment (4), the pilot was given position information and was allowed to select his own course throughout the approach, with the controller acting predominantly as a monitor. While this technique appeared to be satisfactory, it seemed possible that a more highly structured technique might have additional value. By making the control task more structured, the flexibility of choice of alternate flight paths would be reduced. Thus, the situation could become somewhat less ambiguous and the possibilities of confusion might be reduced. However, under heavy traffic loads a narrow range of choices might produce an undesirable level of waiting-line congestion because of incomplete utilization of the available space. Also the limitation of flight path choice would force certain aircraft to travel some distance from a straight-in approach in order to reach an assigned flight path. Thus, it can be seen that the choice of procedures to be employed with API facilities could be critical to the over-all effectiveness of the system.

The task structure required to evaluate the alternatives posed above could be imposed on the system either through the inclusion of physical-geographical restraints or through the use of standard procedural requirements. As an example of physical-geographical restraints, additional structure could be provided by techniques such as the inclusion of ground reference points (GRP) in the system or the inclusion of fixed approach paths (FAP). Procedural requirements here relate to the degree of option allowed the controller in his use of the facilities.

In summary, the present study was accomplished in two experimental steps. The first step was primarily an investigation of the interaction effects of target identification and the use of API equipment. In this step the API display was

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structured by the inclusion of group reference points and three variants of control procedure were compared. Between the first and second step, expert evaluation of the effects of structuring of the API display configuration was obtained from professional controllers. The second step was a direct comparison of the unstructured API configuration with an API plus GRP, and with an API plus FAP.

STEP I

Method

Apparatus.—The present experiment is the twelfth in a series to employ the OSU Electronic Air Traffic Control Simulator (1), a device developed by the OSU Department of Electrical Engineering for use in the Laboratory of Aviation Psychology. The simulator consists of 30 target generators mounted in console pairs, together with a variety of display components. Each of the target generators is capable of producing an independently controllable blip that simulates the radar returns from an airborne aircraft. The basic displays used by the controllers were simulated Plan Position Indicator (PPI) scopes. The simulation is provided by a 12-in diameter cathode ray tube (CRT) having about 9 in. of useful display diameter.

Communication between pilots and operators was provided by a relatively noise-free, three-channel intercommunication system. All communications were recorded, and photographs (1 frame/sec.) of one of the PPI displays were taken during all problems.

The API displays used in this study were 5-in. cathode ray tubes mounted above each target generator console. An overlay clamp attachment allowed the target generator operator to insert a display of a type similar to that used by the controller over the face of his CRT. The pilot thus had a display of the aircraft target blip at the same ground position as observed by the controller. The major difference between the pilots' and controllers' displays (aside from relative size) was that the pilot could see only the position of his own blip, whereas the controller could observe the position of all the aircraft blips in the terminal area. All displays covered an area of 50 mi. in radius and were essentially noise-free.

The control environment.—Two pattern-feeder controllers constituted the control team whose performance determined system effectiveness. The two operators shared the pattern-feeder function equally. Two additional men were always present in the simulated radar control center. The first of these took the nominal role of a pickup controller and acted as an intermediary between the enroute and the terminal system. His task was to follow a predetermined plan of action, consisting solely of passing flight progress slips to the pattern-feeder controllers at prearranged times. He also acted as a general monitor for the conduct of the experiment, checking "pilot" performance and other such activities.

The second additional man took the role of a GCA controller. He accepted properly set-up aircraft at the GCA gate, i.e., he accepted the output of the pattern-feeder controllers if it met certain standards. He thus exercised an important umpire function: he decided whether go-arounds were necessary on the basis of a pattern-feeder failure to achieve objectively specified ranges of speed, heading, and separation of aircraft at the GCA gate, and immediately

ordered such go-arounds if necessary. GCA acceptance requirements were that each aircraft be on a heading within ±10° of 270° and at 2,500 ft. The required pattern speeds for the two types of aircraft were: bombers, 250 kt.; cargo, 200 kt. GCA would not accept aircraft if minimum separation of 30 sec. could not be maintained for the duration of the glide path. These objective standards were well-known to the controllers.

Control Task.—The task of the two-man pattern-feeder controller team was to direct aircraft entering the system at a range of 50 mi., and at varying altitudes, into one of the two GCA gates using minimum flight times and minimum fuel consumption, while maintaining the aircraft separations prescribed by safety rules.

Each problem consisted of 28 aircraft movements, 24 landing and 4 departing. The aircraft entered the system at an average rate of one every 30 sec. or, in terms of rate per controller, one every 60 sec. The total number of aircraft in each problem was divided equally between the two controllers, each controller being responsible for handling 12 incoming and 2 outgoing aircraft.

Each problem included 14 jet bomber and 14 jet cargo-type aircraft. These types were also balanced between the two controllers. The assumed operational characteristics of the two aircraft types represent hypothetical future aircraft. Table 1 gives the programmed performance characteristics of the two types. While these characteristics are hypothetical, they fall within the range of performance which it has been estimated that future air traffic control systems will be required to accept.

The division of the pattern-feeder task between the two operators was accomplished by the use of a modified sector-control arrangement. Assignment of control responsibility was determined by the sector of entry. The total control area was divided in half on the east-west diameter from 270° to 090°. All aircraft entering the north half were handled by one controller and all aircraft entering the south half were handled by the other controller. Inbound aircraft entered the control zone at their prescribed cruising speeds and altitudes, and with headings that would take them within ±5° of their ultimate destination.

Table 1

Performance Characteristics of the Two Types of Aircraft

Type	Cruise Altitude	Cruise Speed	Descent Rate	Descent Speed	Pattern Speed
Bomber	30,000 ft.	400 kt. IAS	12,000 ft./min.	300 kt. IAS	250 kt. IAS
Jet Cargo	25,000 ft.	350 kt. IAS	6,000 ft./min.	250 kt. IAS	200 kt. IAS

The control area included two landing fields, separated by 15 mi. and equidistant from the center of the control zone. The active runways of these two fields were parallel and the final heading for landing in all cases was ± 10° of

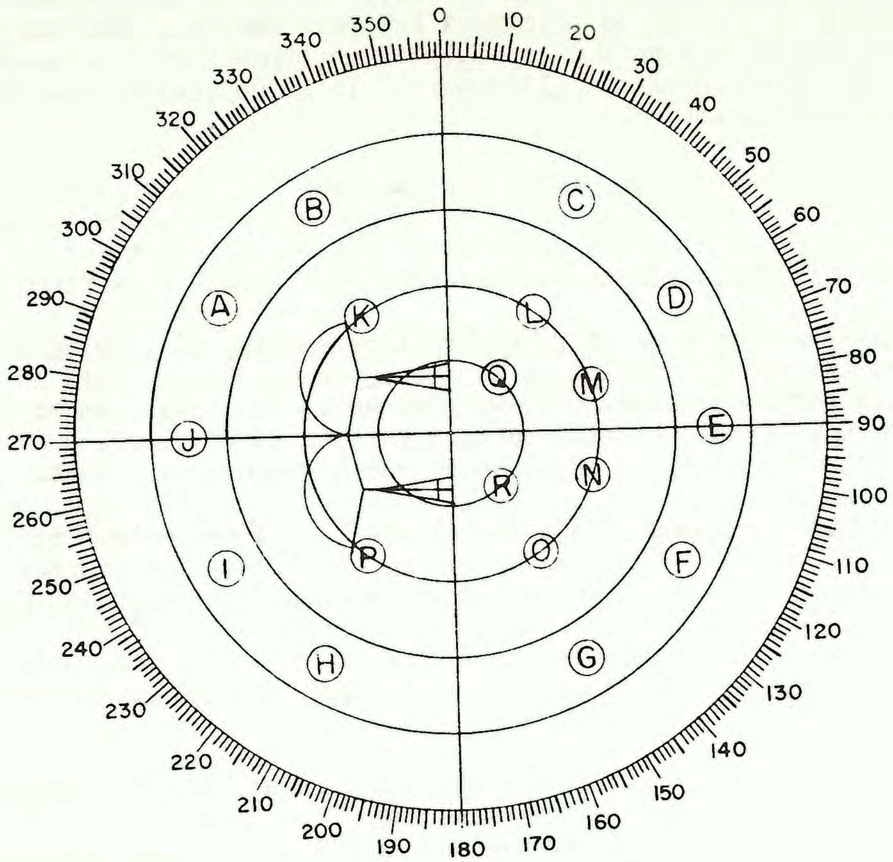

Fig. 1. PPI overlay showing location of GRP and approach and landing facilities in the approach control zone. The lettered circles represent ground reference points (GRP). The pattern-feeder controller could designate a flight path by giving the GRP's as destinations. The pilots could then direct their aircraft to the GRP's by using the API.

270°. The northern field was given the code name Nero Field, and the southern field was given the code name Seneca Field. Figure 1 is a detailed diagram of the control area, as seen on the PPI displays, illustrating the sector divisions and the arrangement of the two airfields.*

The control environment and control problem were designed to provide a complex but realistic presentation of an operation involving several aircraft types. However, it should be remembered that the situation deviated from current field

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* The diagram also shows the arrangement of GRP's which were present in only part of the problems.

conditions in several important aspects. It has been a basic policy of the Laboratory of Aviation Psychology to evaluate the effect of experimental variables first in a system in which the information displayed to controllers has been optimized insofar as possible (with subsequent information degradation if necessary to answer further questions). The control room was illuminated by the Broad Band Blue lighting system (6, 7). No sweep line or transient noise effects were present on the PPI scope. The communication channels were virtually noise-free.

Personnel used as pilots and controllers.—Ten laboratory-trained controllers participated as experimental Ss in the present study. These 10 were selected from a population of 20 male undergraduate students at The Ohio State University, all of whom had had at least 20 hr. of preliminary training in the Laboratory prior to this study (2, 3). Selection was based on level of competence shown in training; the 10 best operators were chosen. All controllers served under all experimental conditions. The order of conditions was random.

The men who served as pilots were also undergraduate OSU students who had had special training in the operation of the target generators and in the accurate portrayal of the pilot role.

Experimental variables.—The major variable in the present study was the presence or absence of one of two display features: (a) target identification, and (b) airborne position information displays containing ground reference points (API + GRP). The four major conditions were (a) neither target identification nor API + GRP, (b) target identification alone, (c) API + GRP alone, and (d) both target identification and API + GRP.

Subsidiary conditions were included as variations of the API + GRP and target identification combination. The base condition (d_1) was one in which the controller was required to specify an approach path (using at least three GRP's) at the time of initial call-in. The first variation on this procedure (d_2) was to modify the restriction on the number of GRP's required to define an approach path. In this condition, the controller was requested to give GRP instructions sequentially (e.g., when an aircraft entered the control zone, it was assigned a "first leg" to a GRP. On completion of the first leg, the aircraft is given a second leg to another GRP, and so on). We have called this condition "segmented GRP". The second variation (d_3) was to allow the controller to use the GRP's in any way that was convenient for him. We have called this condition "optional GRP".

Statistical design.—The total of six conditions evaluated in the present study were arranged in a modified factorial design. Table 2 contains a summary description of the variables and indicates their organization. Order effects were cancelled by a random sequence of presentation which is shown in Table 3.

Each of the five teams of controllers participated under all six of the experimental conditions. Each condition was presented through a short "problem." For each team, there were three problems per evening session for two successive sessions. Each problem was approximately 35 min. in duration with a 10-min. rest interval between problems.

Measures of performance.—Two types of response measures were recorded in this experiment to evaluate the effects of the experimental variables.

Table 2

Experimental Conditions

A. Target identification absent - API absent

B. Target identification present - API absent

C. Target identification absent - API GRP present

D. Target identification present - API GRP present

D_1 Specified approach path procedure

D_2 Segmented approach path procedure

D_3 Optional procedure

Table 3

Sequence of Problems

	Sequence of Problems					
Team	1	2	3	4	5	6
1	D_3	C	D_1	D_2	A	B
2	D_1	B	D_2	C	D_3	A
3	B	D_2	A	D_3	D_1	C
4	A	D_3	C	D_1	B	D_2
5	D_2	D_1	B	A	C	D_3

1. Measures of system efficiency: Each pilot kept a detailed flight record for each of his aircraft. The times recorded were entry into the system, completion of initial speed reduction, beginning of altitude reduction, completion of altitude reduction, completion of final speed reduction, and acceptance by the GCA operator. From these records, mean initial speed reduction time, mean pattern altitude time, mean delay time, and mean fuel consumption were calculated. In addition to these measures, a record of GCA go-arounds was kept by the GCA operator.

Initial speed reduction time is the flight time from entry into the system at 50 mi. out until completion of initial speed reduction for each aircraft. It can be assumed that this score is affected by two factors: (a) controller error, and (b) the amount of flight extension necessary for aircraft to make in order to pass through the first GRP.*

Pattern altitude time is the flight time from completion of altitude reduction until final turnover to GCA for each aircraft. Mean delay time is based on the flight time from entry into the system at 50 mi. out until GCA acceptance, minus the minimum theoretical time it would take the type aircraft to traverse the distance, making all speed and altitude adjustments at the optimal time. This score indicates over-all system efficiency. Mean fuel consumption is determined by three factors: aircraft type, airspeed, and altitude. Fuel consumption, in pounds, was calculated for each aircraft flight.

2. The second major category is safety. Separation errors were tallied for each problem by viewing the photographic films. A separation error was defined as the approach of one aircraft within 30 sec. of another aircraft. This means that 2 mi. or more lateral distance was required in the control zone.

Results

A comparison of the results for the four major conditions is made in Tables 4 through 9. In each case, the conditions are arranged in a ranked series and statistical comparison is between pairs.

The data in Table 4 indicate that the condition having neither target identification nor API is reliably poorer than all others. The use of target identification alone improved performance by 38%, a significant amount. API alone was 4% better than target identification alone and 42% better than neither. The combination of target identification and API improved system performance by only another 2% over the use of API alone.

The delay imposed on the system by the use of ground reference points is illustrated in Table 5. Aircraft under the API condition were required to divert from a straight-in approach and follow the GRP pattern. Thus, time from entry to initial speed reduction was inflated for the API conditions. In this case, the target identification alone condition was superior by 26% over the combined condition. Table 6, however, reveals where the API facility improves system performance. After the aircraft have reached pattern altitude, they are in a very crucial phase of the approach. At this stage, the airspace is relatively crowded and highly precise control is required. During this phase, adding aircraft identification to the system results in a 16% increase in performance. Adding API to the system already having target identification yields another 18% increment in performance. As is revealed in Table 6, just the API alone is sufficient to attain this increment.

* The initial speed reduction command was usually given when the aircraft was 38 mi. from the landing field. Therefore, the operators used the outer GRP as a reference for issuing their command. When the aircraft approached a GRP, the command was given. The time elapsing between entry into the system and completion of the speed reduction indicated the amount of flight extension necessary for the aircraft to reach the first GRP.

Table 4

Comparison of Major Conditions on Mean Per Cent Delay in GCA Acceptance

Rank	Condition	Mean Per Cent Delay	Per Cent Performance Improvement over Next Higher Rank	Reliability of Difference*
1	ID + API	91	---	
2	API	93	2%	NS
3	ID	97	4%	NS
4	Neither	133	38%	P< .05

* The Walsh Test was used to determine significance.

Table 5

Comparison of Major Conditions on Mean Initial Speed Reduction Time

Rank	Condition	Time from Entry to Speed Reduction (in seconds)	Per Cent Change from Next Higher Rank	Reliability of Difference*
1	ID	143	---	
2	ID + API	180	26%	P< .01
3	Neither	188	4%	NS
4	API	192	2%	NS

* Significance level evaluated by the Walsh Test.

Table 6

Comparison of Major Conditions on Mean Pattern Time

Rank	Condition	Time Average at Pattern Altitude (in seconds)	Per Cent Change from Next Higher Rank	Reliability of Difference*
1	API	376	---	
2	ID + API	379	1%	NS
3	ID	446	18%	P< .02
4	Neither	537	16%	P< .05

* Significance level evaluated by the Walsh Test.

Table 7

Comparison of Major Conditions on Mean Excess Fuel Consumption

Rank	Condition	Per Cent Excess Fuel Consumption	Per Cent Change From Next Higher Rank	Reliability of Difference*
1	ID + API	97	---	
2	API	97	0%	NS
3	ID	104	6%	NS
4	Neither	119	14%	P <.05

* Significance level evaluated by the Walsh Test.

Table 8

Comparison of Major Conditions on Mean Number of GCA Go-Arounds per Aircraft

Rank	Condition	Mean Number of GCA Go-Arounds per 100 Aircraft	Per Cent Change From Next Higher Rank	Reliability of Difference*
1	ID + API	4	---	
2	API	4	0%	NS
3	Neither	4	0%	NS
4	ID	6	50%	NS

* Significance level evaluated by Walsh Test.

Table 9

Comparison of Major Conditions on Mean Number of Separation Errors per Aircraft

Rank	Condition	Mean Number of Separation Errors per 100 Aircraft	Per Cent Change From Next Higher Rank	Reliability of Difference*
1	API	7	---	
2	Neither	7	0%	NS
3	ID + API	8	14%	NS
4	ID	8	0%	NS

* Significance level evaluated by the Walsh Test.

Table 10

Comparison of Basic API Condition with Variants

Criterion Measure	Basic API (Entire Approach Path Specified)	Optional API	Segmented API
Mean Per Cent Delay	91	95	101
Mean Initial Speed Reduction Time (in sec.)	180	162	171
Mean Pattern Time (in sec.)	379	421	445
Mean Per Cent Excess Fuel Consumption	97	100	102
Mean Number of GCA Go-Arounds per 100 Aircraft	4	10	7
Mean Number of Separation Errors per 100 Aircraft	8	10	11

Table 7 shows a record for excess fuel consumption which is similar to the record for delay time. Here the three systems having one or both aids are closely grouped, all being from 14 to 20% superior to a system with neither aid present.

Tables 8 and 9 are compilations of GCA go-arounds and separation errors, respectively. Statistical reliability of the difference between conditions is not demonstrable with either of these two criteria. However, one or another of the systems including API is slightly superior in both cases.

Table 10 is a compendium of all criteria comparing the three procedural variants of the API + GRP condition. On all but one measure (initial speed reduction time), the procedure requiring entire approach path specifications is superior. However, the differences are small and not statistically significant.

Discussion

The results confirm previous findings (4, 8, 9) that the addition of either target identification or API to the system will facilitate system performance. A detailed analysis of the data, however, raises several difficult questions. First, it is apparent that the combination of the two facilities, target ID and API, result in proportionately less improvement in the system than the effect of either alone. That is, we have apparently arrived at the zone of diminishing returns

within the over-all configuration of the system and the class of operators employed in this particular study. While such a diminishing-returns effect is to be expected since every system presumably has a finite upper limit on performance output, there are other significant parameters exposed by the data which must enter into any final evaluation of the usefulness, jointly or separately, of target ID and API facilities.

The first matter of concern involves the employment of the characteristics of the API facility to derive target identification information indirectly. Such an eventuality was anticipated prior to the inception of the study and it turned out to be quite feasible in operation. Since the pilot and ground controller both had position information available which was oriented to the same reference system, the controller was able to query pilots regarding their identification on this basis (i.e.,"Aircraft 2 mi. North of Ground Reference Point Alpha, call in identification!"). It is apparent that if such an expedient were efficient in itself, the addition of continuous target identification would have a somewhat diminished impact on system performance.

In the second instance, the present study arbitrarily employed a single ground reference point configuration in conjunction with the API equipment. A comparison of the present findings with those obtained in the previous study of API (4) raises the suspicion that either the GRP's had little utility in the over-all system configuration or that the particular arrangement chosen was faulty.

In order to extend the scope of conclusions affecting the total problem as initially envisaged, several follow-up actions seemed appropriate. The first such was an extended consultation with professional controllers from the Directorate of Flight and All Weather Testing, WADC. While such consultation is a normal procedure in the conduct of ATC system experimentation in this Laboratory, the activity was made more formal and explicit in the present case.

The controllers were asked first to act as operators in the simulated system under selected conditions from Step I in this study. Following this, they were asked to present their opinions on the problems raised both verbally in conference and by written summary. An analysis of their commentary yielded the following results: (a) target identification by geographical location was awkward and time consuming compared to a continuous ID system—the latter was strongly preferred; (b) with continuous target ID absent, some form of geographical structuring in the approach zone was regarded as promising; and (c) regardless of the level of geographical structuring, it was felt that employing strict procedural requirements in conjunction with these facilities was to be avoided. In addition to these points, a revision in the number and location of the GRP's was suggested. It was recognized that a comparative empirical evaluation of all possible geographical configurations was not feasible within the confines of a single experiment. Thus, a selection based on expert opinion seemed a reasonable alternative method of selection.

STEP II

Method

Two alternative geographical structuring techniques evolved from the preceding tests and discussions: a GRP set-up in which a greater number of positions would be employed compared to the configuration used in Step I, and a configuration employed fixed approach paths (FAP) in place of GRP's. In order to obtain an indication of the usefulness of such techniques in attaining target identification information, all problems were conducted without the clock-code system employed in Step I. Apparatus, controllers, and control problems were the same as in Step I with the exception of the fact that a single landing field and a single pattern-feeder controller were employed.

Experimental variables.—Three possible configurations of the API facility were compared in this study: (a) a simple API system in which no special ground references were provided; (b) a condition of API combined with GRP, with the GRP located to conform to the judgment of optimum placement made by professional controllers, and (c) a condition of API combined with fixed approach paths (FAP). In the FAP condition there were seven such straight-in paths located in the approach zone. Figures 2 and 3 show the terminal configuration for the GRP's and the FAP's, respectively (the controller saw only GRP or only FAP or neither during any given problem). As was the case in Step I, the pilot had the same overlay set-up on his display that the controller had, and the overlay set-up was varied from problem to problem on the pilot's display to correlate with what was present for the controller.

Traffic Control procedures.—Prior to the experimental problems, the eight operators were fully briefed on the task. Each of the operators was given one 20-min. familiarization trial with each of the three conditions. Each operator was encouraged to make full use of any procedures which he felt would increase his efficiency.

Statistical design.—Three different conditions were sampled. The order of presentation is shown in Table 11. The order of presenting the conditions was such as to balance learning and fatigue effects.

Table 11

Order of Presentation of Conditions

Subject	Sequence of Conditions		
1	A	B	C
2	A	C	B
3	B	C	A
4	B	A	C
5	C	A	B
6	C	B	A
7	A	B	C
8	B	C	A

Note:— A = API; B = API + GRP; and C = API + FAP

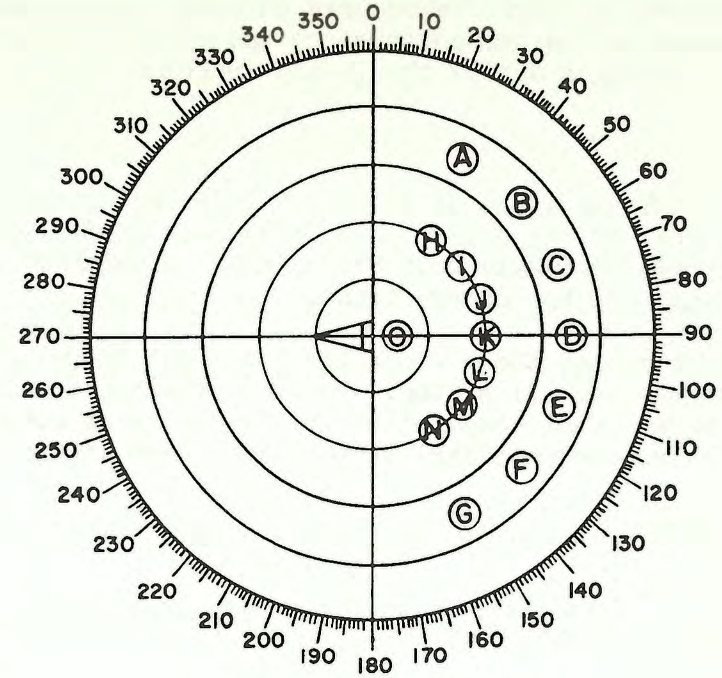

Fig. 2. Configuration of ground reference points in the approach zone.

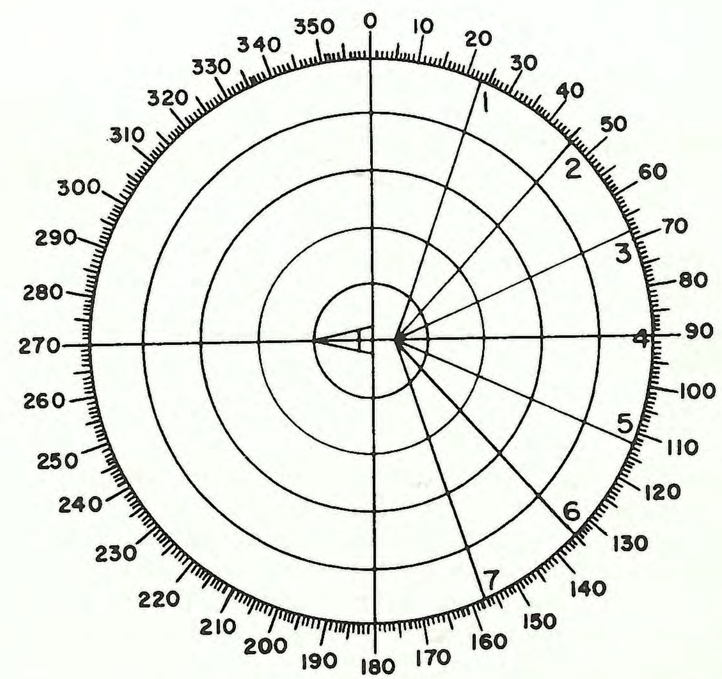

Fig. 3. Configuration of fixed approach paths in the approach zone.

The same measures of performance used in Step I were employed in this study. An additional measure of system performance was the total number of aircraft accepted by the GCA operator during the 20-min. problem.

Results

The API without additional structuring was superior to the alternatives of API + GRP and API + FAP on all criteria employed. The differences are relatively small and are not statistically reliable. Such a consistent trend, however, lends some confidence to the observations.

Table 12 reveals that there was a 12% increment in delay when GRP's were added to the unstructured API system. Fixed approach paths were even less efficient. On both excess fuel consumption and frequency of separation errors, the superiority of the nonaugmented API system approaches significance by statistical test.

Table 12
Comparison of Three API Conditions

Criterion Measure	Condition API	API + GRP	API + FAP	χ^2_r	P
Mean Per Cent Delay	61	73	79	3.25	NS
Mean Per Cent Excess Fuel Consumption	75	83	89	4.75	.12
Mean Number of GCA Go-Arounds per Aircraft	.10	.11	.14	0.25	NS
Mean Number of Separation Errors per Aircraft	.10	.12	.15	4.56	.13
Mean Number of Aircraft Processed per 20-min. problem	13.4	12.8	12.8	0.71	NS

Discussion

The findings reported, while still tentative, seem to reflect the ability of the controller to make use of what might be called the "inherent structure" of the system. In the absence of fixed points or paths, the controllers called upon the range and azimuth coordinate system that was available to both controllers and pilots. The controllers employed this universally present structure to provide target identification on demand and to organize the traffic flow using the range and azimuth referents in place of GRP's.

Imposing additional structure on the system through the use of GRP and FAP not only does not appear to benefit performance, but rather appears to degrade it. The mechanisms involved seem to entail factors of timing, path stretching and airspace congestion.

In this regard, one factor is that diversions from a direct approach are necessitated in order to follow an FAP or an approach path composed of a succession of GRP's.

Moreover, the GRP's and FAP's tend to concentrate aircraft in narrow regions, when there is no functional utility for such concentration, by establishing a final common path early in the approach.

Such considerations point up the general conclusion that maximum flexibility both in task structure and procedures leads to optimum utilization of the skills and capacities of the human link in the system configuration under normal operating conditions.

SUMMARY AND CONCLUSIONS

In this study, two experimental steps were employed to explore the interaction effects of an airborne position information (API) display with the display of target identification. Several variants within the class of systems employing API were also compared and analyzed.

The first step was an experimental comparison of four basic conditions: (a) an unaided system (neither target identification nor API); (b) a system with target identification alone; (c) a system with API plus ground reference points (GRP) alone; and (d) a system employing both target identification and API + GRP.

The result of this comparison was an over-all ranking of conditions as follows: ID + API + GRP > API + GRP > ID > unaided system, where ID + API + GRP was the most effective arrangement. The greatest difference was between the unaided system and ID alone.

Three procedural variants of the API + GRP system were also compared: (d_1) an entirely specified approach path procedure; (d_2) a procedure wherein controllers were requested to use a single GRP for each segment of the approach and (d_3) an optional procedure wherein the controllers could use the GRP at their own discretion.

Neither of the two variants was as effective as the entirely specified approach path arrangement which called for assignment of an approach path made up of three or more GRP's at the time of initial entry into the approach zone. However, detailed analysis and cross-checking with results of previous studies brought the entire concept of geographical structuring into question. Therefore, between the conclusion of the first step and the onset of the second step, an expert evaluation of the system by four professional controllers from the Directorate of Flight and All Weather Testing, WADC, was undertaken. These men controlled traffic for short, standard periods with the various configurations and then were requested to summarize their views. The professional controllers were interested in the API + GRP configuration, but were wary of the use of an overly complex or overly rigid procedure.

The second step was an experimental comparison of three API systems without target identification. The three were (a) a simple, unaugmented API system, (b) API plus ground reference points, and (c) API plus fixed approach paths.

The results indicated tentatively that the API system without additional restrictions was superior.

The following conclusions are drawn:

1. The introduction of API to a radar approach control system can be used to partially compensate for lack of target identification, although some penalties are involved in such an expedient.

2. When target identification is present, a relatively moderate increment in performance is noted when an API system (augmented with GRP) is employed.

3. Controllers prefer a system which allows maximum choice of procedures in the use of a facility such as API and GRP.

4. The technique of target identification by geographical location suggested by the GRP-augmented API facility can be accomplished with equal or superior effectiveness without the GRP or other such geographical structuring (i.e., FAP) present in the system.

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